

Civil Engineering in 2025

Blaine D. Leonard, P.E. UDOT Research Division January 17, 2007

"He who does not look ahead, remains behind" - Spanish Proverb

Where do we begin?

- The Engineer of 2020: Visions of Engineering in the New Century, National Academy of Engineering, 2004
- Rising Above the Gathering Storm: Energizing
 America for a Brighter Future, National Academy of Sciences, 2006.
- The Vision for Civil Engineering in 2025, ASCE, 2006
- Seven Revolutions: What Will the World Look Like in 2025?, Center for Strategic and Int'l Studies, 2006.

"640K ought to be enough for anybody"

- Bill Gates, CEO/Founder, Microsoft, 1981

"Television won't last because people will soon get tired of staring at a plywood box every night"

Darryl Zanuck, movie producer, 1946

"I think there is a world market for maybe five computers"

Thomas Watson, Chairman, IBM, 1943

"A guy ought to be very careful in making predictions, especially about the future"

- Yogi Berra

STEPS FOR LOOKING FORWARD

- Trends of the Past
- Current Conditions and Challenges
- Predictions of the Future
- Envision Who We Will Be
- A Plan for How to Get There

- **8** Percent of homes had a telephone
- **14 percent of homes had a bathtub**



- The average wage was \$0.22 per hour
- Less than 6 percent of Americans were graduated from High School

- Average life expectancy was 47 years
- >95 percent of births took place at home
- >90 percent of physicians had no college education



Civil Engineering in 2025

- There were only 230 reported murders
- **The leading causes of death were:**
 - Pneumonia and influenza
 - Tuberculosis
 - Diarrhea
 - Heart Disease
 - Stroke



- There were 144 miles of paved roads
- There were 8,000 cars in the US

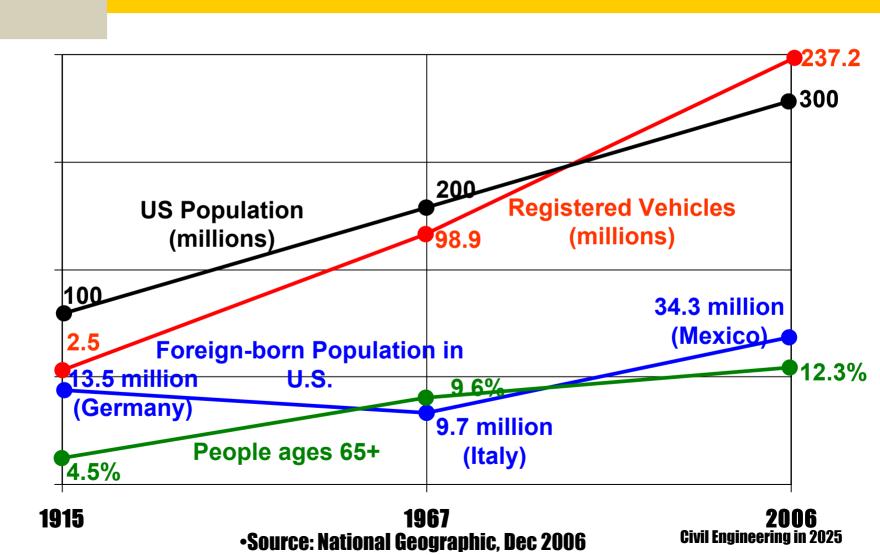




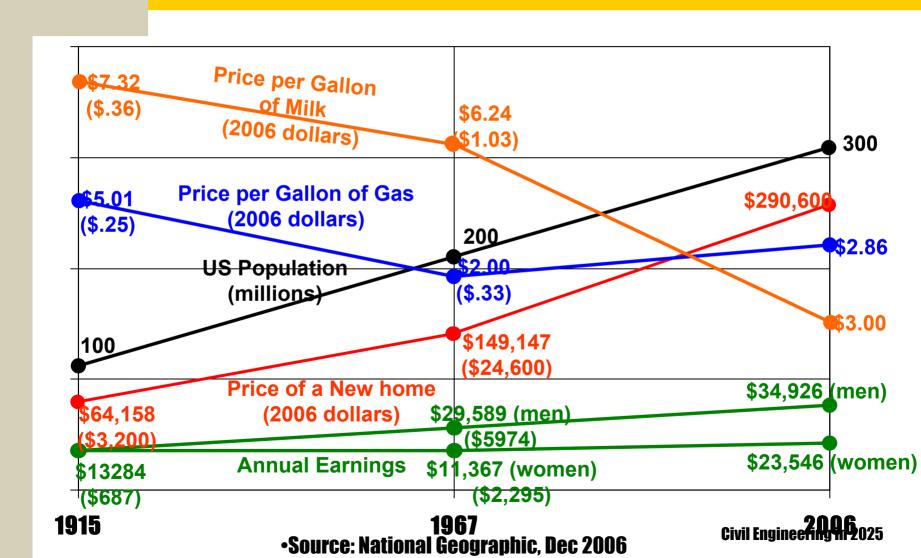
- The population of Las Vegas was 30 people
- **℃ California was the 21st most populous state**

- "Change is constant, but, on an absolute basis, our world has changed more in the last one hundred years than in all those preceding."
 - Educating the Engineer of 2020, National Academy of Engineering

100 YEARS OF PROGRESS



100 YEARS OF PROGRESS



POLITICAL STRUCTURES

- People living under democratic rule:
 - 1900: 25 countries, 12% of world population
 - 1950: 42% of world population
 - 2000: 140 of the world's nearly 200 countries hold regularly scheduled, multi-party elections, 63% of world population
 - Sources: Center for Strategic & Int'l Studies (CSIS);
 Peterson (2006)



- Interstate Highway System
 - 41,000 Miles
 - \$114 billion construction cost
 - 35 years to construct



- "We do not have great highways because we are a great nation, we are a great nation because we have great highways"
 - -- DeWitt C. Greer (1902-1986), Chair Texas Highway Commission

100 YEARS OF PROGRESS

- Great Bridges
 - Golden Gate, etc
- Dams, Power Plants and Water Distribution Systems
 - Hoover Dam
 - Glen Canyon
 - Central Utah Project
- Water Purification, Distribution, and Treatment Systems



100 YEARS OF PROGRESS

- "... The greatest advances in improving human health were the development of clean drinking water and sewage systems. So, we owe our health as much to civil engineering as we do biology."
 - Lewis Thomas, Former head of Yale Medical School & Memorial Sloan-Kettering Cancer Center

So, where are we now?

KNOWLEDGE

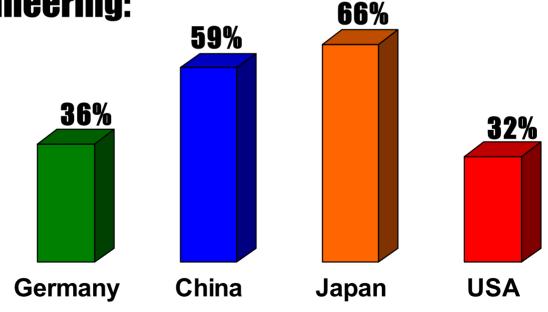
- Scientific and engineering knowledge presently doubles every 10 years
 - B.T. Wright, VP engineering, Rockwell Collins
- Knowledge is the source of all sustainable competitive advantage
 - BT Wright, citing Drucker, Welsh

EDUCATION

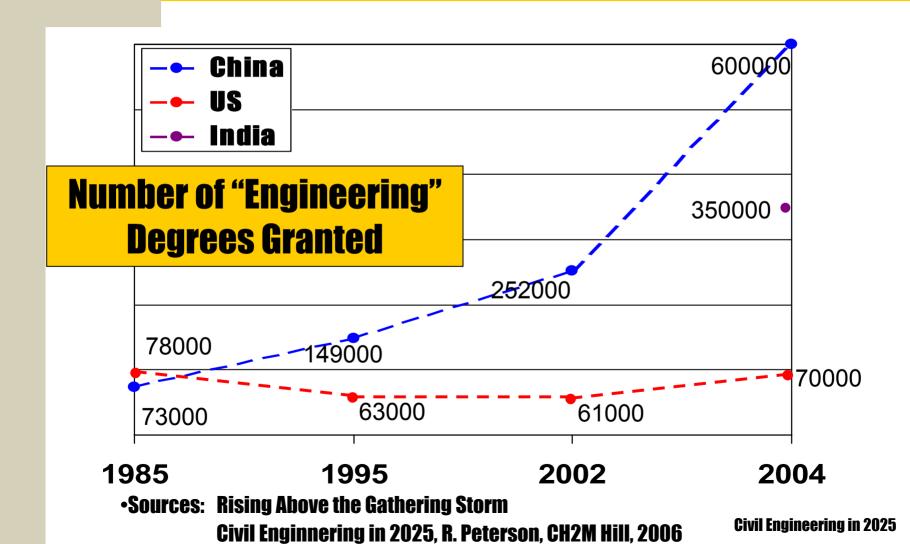
- **№ U.S.** 12th Graders recently performed below the international average for 21 countries on a test of general knowledge in math and science.
- Eleven nations outperformed the US on tests administered to students who had taken precalculus, calculus, or AP calculus
 - Rising Above the Gathering Storm, National Academies

EDUCATION

Undergraduates who receive degrees in science and engineering:
66%



Source: Rising Above the Gathering Storm



EDUCATION

- Today's US engineering graduates have taken:
 - 20 fewer credits than their 1920 counterpart
 - 18 fewer credits of engineering topics

 Thus, while the complexity of engineering and the engineering project is increasing, our formal education is decreasing.

Source: <u>Civil Engineering Body of Knowledge</u>, ASCE

RESEARCH

- In 2001, US Industry spent more on tort litigation than on R&D.
- In 2003, only three American companies ranked in the top 10 recipients of patents granted by the US Patent and Trademark Office

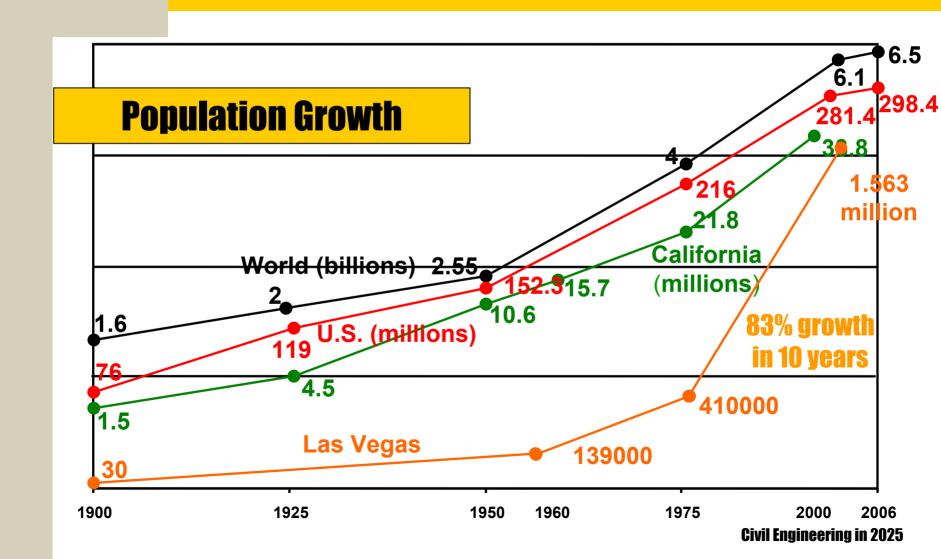
Source: Rising Above the Gathering Storm

TECHNOLOGY

- For the first time, the most capable highenergy particle accelerator on Earth will, beginning in 2007, reside outside the US
- The US is today a net importer of hightechnology products.
 - US share of global high-tech exports has fallen in the last 2 decades from 30% to 17%
 - US trade balance shifted from \$33 bill in '90 to -\$24 bill in 2004

GLOBAL ECONOMICS

- Of the world's 100 largest economic entities, 42 are now <u>corporations</u>, not countries
- **Wal-Mart revenues for 2002:**
 - \$246 billion
 - the 19th largest economic entity in the world
 - Gross Nat'l Income of Sweden: \$229 billion
 - Wal-Mart is the largest employer in the US



<u>POPULATION</u>

- A 50-year old female today has an 85% chance of reaching 100-years old
- Insurance Actuarial tables assume a female child born today will reach 120-years old

INFRASTRUCTURE

Severe highway bottlenecks have increased by 40% during the past five years

Americans spend 3.5 billion hours per year in traffic at a cost of \$63.5 billion in wasted time

and fuel

> 27% of the 590,750 bridges nationwide are structurally deficient or obsolete

Civil Engineering in 2025

INFRASTRUCTURE

- Freight tonnage will increase 50% by 2020
- Aviation passenger traffic is projected to grow by >39% between 2006 and 2016

<u>INFRASTRUCTURE</u>

- ★ 50% of the 257 locks on the 12,000 miles of inland waterway operated by the Army Corps of Engineers are functionally obsolete
- > 75% of the nation's public school buildings fail to meet the basic needs of children

Source: "Guiding Principles for Strengthening America's Infrastructure", CSIS

INFRASTRUCTURE

- A five year investment of \$1.6 trillion is needed to remedy our current infrastructure condition
 - Only 50% of that is currently in the federal, state, and local budget now
 - 2005 Infrastructure Report Card, ASCE

<u>INFRASTRUCTURE</u>

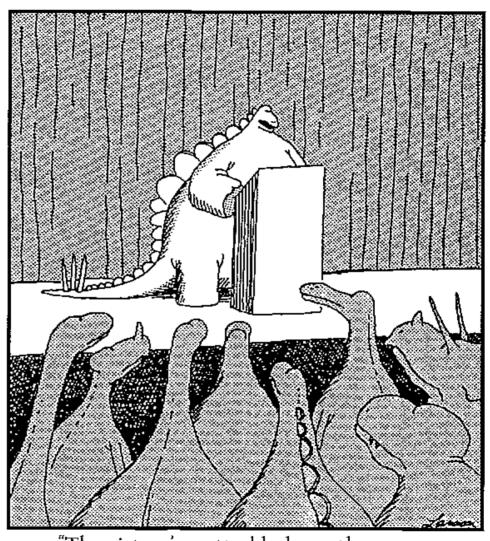
- Federal investment in public infrastructure has declined substantially over the last 30 years
 - state and local governments now spend nearly three times as much as their federal counterpart
 - In the 1960's, federal and non-federal shares of infrastructure spending were nearly equal
 - Source: "Guiding Principles for Strengthening America's Infrastructure", CSIS

<u>INFRASTRUCTURE</u>

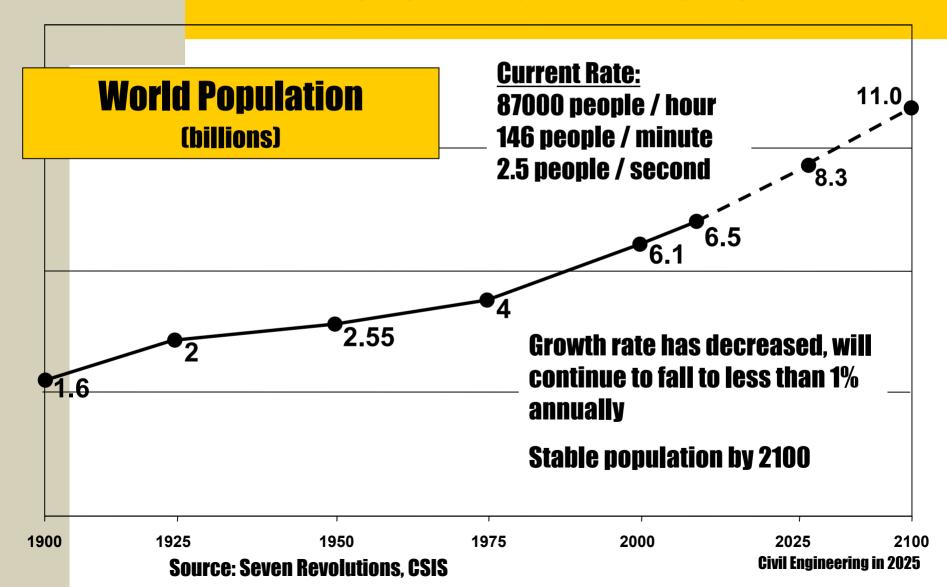
- "We are both <u>under-investing</u> in infrastructure and investing in the <u>wrong</u> projects"
 - Center for Strategic & International Studies (CSIS)

QUALITY OF LIFE

- > 17,000 people in 16 countries were asked: "Suppose a young person who wanted to leave this country asked you to recommend where to go to lead a good life what country would you recommend?"
 - Respondents in only one country (India) indicated the US
 - Except for India, Poland and Canada, no more than 10% of the people in the other nations said they would recommend the US
 - Canada and Australia ranked the highest
 - Source: Rising Above the Gathering Storm, National Academies



"The picture's pretty bleak, gentlemen. . . . The world's climates are changing, the mammals are taking over, and we all have a brain about the size of a walnut."



POPULATION

- Populations of most developed countries will actually be smaller in 2025.
 - The US is the only developed nation which has a growing population
- **80%** of the world's population will be in countries least capable of supporting further growth.

POPULATION

- **Eight countries will account for half of the world population growth through 2050:**
 - Bangladesh
 - China
 - India
 - Nigeria

- Pakistan
- -the U.S.
- Ethiopia
- Democratic Republic of the Congo.

POPULATION

by 2025, population projections are:

- Bangladesh: 206 million

– China: 1.45 billion

India: 3.7 billion

Indonesia: 272 million

Nigeria: 202 million

Pakistan: 250 million

– U.S.: 335 million

<u>POPULATION</u>

- Over the next 20-years, the developing world will experience an enormous youth bulge.
 - >50% of the world's population could be under 18 years old in 2020.
 - Youth bulge likely in regions of recent social and political tension
 - An excess of idle youths unable to find employment will make situations worse
 - Source: Seven Revolutions, CSIS

<u>Urbanization</u>

- **By 2025, 60% of the world's population will be in urban areas.**
- Today, up to half of the population in the largest cities in the developing world is living in unplanned and illegal squatter colonies, highly vulnerable to disease and natural disasters.

<u>Urbanization</u>

By 2015, 21 cities will have populations over 10 million.

Top three:

– Tokyo: 27.2 mill

Dhaka, Bangladesh: 22.8 mill

- Mumbai, India: 22.6 mill (formerly Bombay)

INFRASTRUCTURE GROWTH

№ 80% of the infrastructure to be developed on the planet in the next 20 years will occur outside the US

Ralph Peterson,
 Chairman, CH2M Hill, 2006



ENERGY / NATURAL RESOURCES

- More than 60% of the increase in world primary energy demand between 2000 and 2030 will come from developing countries. Their share will increase from 30% to 43%
- To feed the 8 billion people expected by 2025, the world will have to double food production

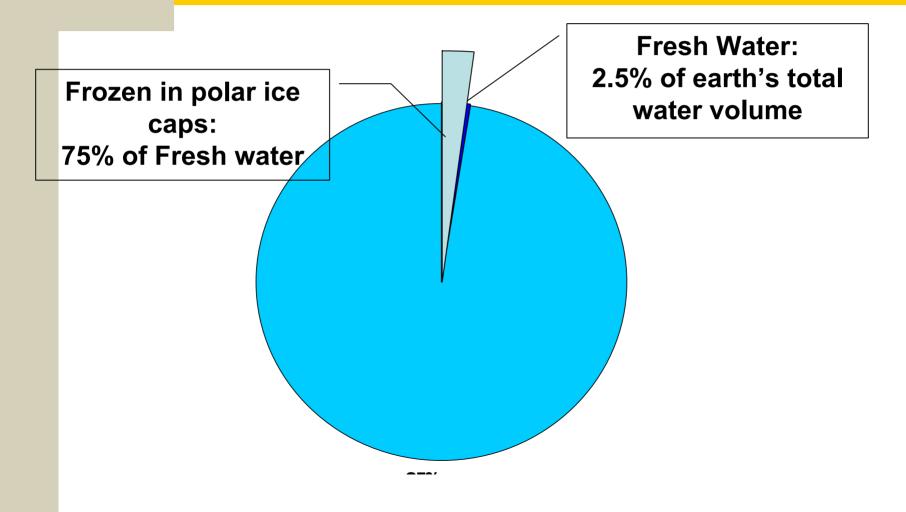
Source: Seven Revolutions, CSIS



ENERGY / NATURAL RESOURCES

- 1.7 billion people currently lack access to safe drinking water
 - 26% of the world population

Source: Seven Revolutions, CSIS



SECURITY

- The world of 2025 presents a high-risk environment
 - An on-going threat of large-scale natural and man-made disasters.
- Gradual global warming will likely raise ocean levels
 - More than half of the world's population lives within 50 miles of coastal areas.

EDUCATION

- Last year, MIT Pres Charles Vest announced that over the next ten years, MIT will make all its courses available over the web without cost challenging what he calls the "privatization of knowledge"
- By 2020, Engineers in the US will need 30 hours of post-BS education to sit for the PE exam in most states

EDUCATION

- **The Engineer of 2020 will need to:**
 - learn much new technical information and techniques and
 - be conversant with and embrace a whole realm of new technologies

Source: Educating the Engineer of 2020, National Academies

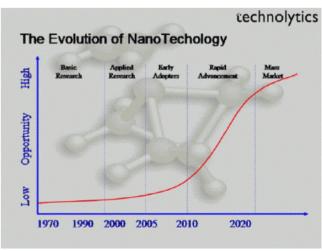
TECHNOLOGY

- Moore's law of doubling yields and falling prices will continue through 2020
- Transisters per chip:
 - **1965: 30**
 - 2010: 10 billion, according to Intel
- Intelligent sensors, able to sense any kind of physical phenomena, will plunge in cost
 - Michael Rogers, practical futurist

TECHNOLOGY

- "Nanotechnology will replace our entire manufacturing base with a new, radically more precise, radically less expensive, and radically more flexible way of making products"
 - Dr. Ralph Merkle, Georgia Tech College of Computing





TECHNOLOGY

- Current applications of nanotechnology (micro-electro-mechanical machines) are already extensive, ranging from controlling operations in cars to uses in a variety of medical procedures. This trend will revolutionize material science, chemistry and physics.
 - Seven Revolutions, CSIS

TECHNOLOGY

A research team recently assembled 70 Sony Playstation devices into a super computer capable of a half trillion operations per second



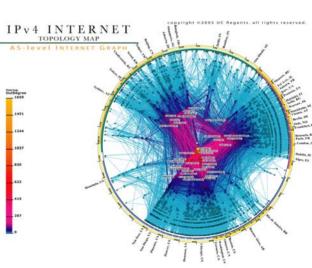
Advances in molecular and quantum computing will continue the trend in increasing processing speeds.

TECHNOLOGY

We have reached the point at which "a fiber the size of a human hair can deliver every issue of the Wall Street Journal ever made

in less than a second"

Nicholas Negroponte, MIT



TRANSPORTATION INFRASTRUCTURE

- Advanced video and computer technology support congestion pricing systems that have reduced automobile traffic in London by a third.
 - Bus lines now move twice as fast
 - Carbon dioxide emissions reduced by 20 percent
 - Emissions of harmful particulates and nitrogen oxides reduced by 12 percent.
 - CSIS

TRANSPORTATION INFRASTRUCTURE

- 200 years ago, our top speed was about 6 miles per hour
- > 100 years ago, our top speed was 60 miles per hour
- Today, our top speed is about 600 miles an hour
- **Where will we be in 100 more years?**
 - Ben Schwegler, Chief Engineer, Walt Disney Imagineering









TRANSPORTATION INFRASTRUCTURE

- "Civil engineers created an entire transportation system, and now they are just fixing it. We don't need engineers to FIX these; Civil engineers should be out creating the NEXT system"
 - Ben Schwegler, Chief Engineer, Walt Disney Imagineering





Far better it is to dare mighty things, to win glorious triumphs, even though checkered by failure. than to rank with those poor spirits who neither enjoy much nor suffer much, because they live in the gray twilight that **knows not victory nor defeat."**

-- Theodore Roosevelt, 26th U.S. President

SUMMIT ON THE ENGINEER OF 2025

- > 50 Industry Leaders gathered to consider the future of Civil Engineering, what we should be, and how to prepare
- They produced:
 - A "Vision Statement" of who the Civil Engineer is in 2025
 - A "portrait" of the desired attributes and capabilities of the Civil Engineer in 2025
 - A road map for future actions



Entrusted by society to create a sustainable world and enhance the global quality of life, civil engineers serve competently, collaboratively, and ethically as master:

- planners, designers, constructors, and operators of society's economic and social engine, the built environment;
- stewards of the natural environment and its resources;
- innovators and integrators of ideas and technology across the public, private, and academic sectors;
- managers of risk and uncertainty caused by natural events, accidents, and other threats; and
- leaders in discussions and decisions shaping public environmental and infrastructure policy.

Civil Engineering in 2025

ENGINEERING PRACTICE

- Intra-disciplinary, cross-disciplinary, and multi-disciplinary collaboration on projects and in research and development.
- More advances in areas such as information technology, intelligent infrastructure, and digital simulation

ENGINEERING PRACTICE

Design team includes a multitude of participants, many in related areas of management, environmental sciences, social sciences, legal, planning, geographic and other disciplines.

ENGINEERING PRACTICE

- Real-time exchange of ideas in decentralized work environments.
 - cyberspace connections
 - wireless hand-held, voiceactivated devices



ENGINEERING PRACTICE

- Worldwide marketplace for engineering services means:
 - Jobs will move freely
 - Cultures, knowledge, and economies will be joined together
 - US engineers must be able to bring additional value to offset the global challenge

EDUCATION

- Trained and well-equipped to be at the forefront of adapting and integrating new technologies
- Focus on the construction project must be multi-faceted and multi-disciplined and holistic.

EDUCATION

- **Important attributes for engineering teams:**
 - excellence in communication,
 - ability to communicate using technology,
 - Ability to understanding complexities of a global market,
 - well developed people skills,
 - flexibility,
 - receptiveness to change, and
 - mutual respect.

SUSTAINABILITY

- Recognize the reality of shrinking resources
- Necessity of adopting sustainable practices and design
- The need for social equity in the consumption of resources
- Incorporate recycling (recycled materials, or making project components recyclable)
- New buildings actually produce more energy that they consume.



ENERGY / TRANSPORTATION

- Increased use of clean coal along with carbon sequestration, nuclear, and renewable sources such as wind, solar, waves, and geothermal
- Increased use of mass transit, less reliance on personal automobiles:
 - reduced demands for fossil fuels
 - fuel cell technology or renewable resources such as ethanol.



<u>INFRASTRUCTURE</u>

- Improved water purification methods, desalination technologies, and increasing use of closed-loop systems
 - use of gray-water systems
 - purify water at the point-of-use in de-centralized systems
 - Infrastructure financing routinely involves lifecycle costing analysis with public debate as to tradeoffs for different issues.

PUBLIC POLICY

- Provide critical technical guidance in defining public policy throughout the government and global commissions.
- Define the research agenda for nanoscience, nanotechnology, and biotechnology applications in the infrastructure



TECHNOLOGY

- Full application of information technology and data management, to improve how facilities are designed, engineered, built, and maintained.
- Intelligent infrastructure (e.g., embedded) sensors, real-time onboard diagnostics)
- Real-time monitoring, sensing, data acquisition, storage, and modeling, leading to informed decisions.

Civil Engineering in 2025



INNOVATION

- No longer risk averse to new technology
- W Highly-integrated planning and construction tools, supported by fourdimensional databases

Broadly speaking, there are only two futures for civil engineering: the one the profession creates for itself or, in the void, the one others create for civil engineering.

PREPARING FOR THE FUTURE

Proposed Long-Term Actions:

- More robust C.E. education
 - Leadership
 - Multi-faceted non-technical skills
- Better definition of engineering team organizational structure
 - Civil P.E. as the master integrator



Proposed Long-Term Actions:

- Increased involvement in public forums
 - Determine future directions
 - Gain public trust
 - Direct influence through elected office
- Greater collaboration and communication
 - Balance sustainability with infrastructure needs



Proposed Long-Term Actions:

- Increased research and development
 - Mitigate natural disasters
 - Implement innovations
- Greater emphasis in ethics
 - Education and training
 - Global ethics improvements
 - C.E. serve as the role model



What can you do to begin implementing these steps toward the 2025 vision for Civil Engineering?

"Destiny is not a matter of chance; it is a matter of choice."

-- Statesman William Jennings Bryan